

SEMI-ANNUAL PROGRESS REPORT

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For the Period Beginning July 1, 1972 and
Ending December 31, 1972

CR - 129986

A. Title of Investigation:

An Interdisciplinary Analysis of ERTS Data for
Colorado Mountain Environments Using ADP Techniques

ERTS-1 Proposal No: SR030/040

B. GSFC Identification Number: UN103

Principal Investigator: R. M. Hoffer

The following material represents a summary of research efforts over the past six months at both LARS/Purdue University and INSTAAR/University of Colorado. Principal work emphasis over this period has been placed on (a) the location, acquisition, and preparation of baseline information necessary for the computer analysis and (b) refinement of techniques for analysis of MSS data obtained from ERTS. Analysis of ERTS data has been performed for several test areas both within and outside the Colorado test sites. Analysis of the first frame of data collected by the ERTS multispectral scanner system, over the Lake Texoma area has proven very valuable for determining the best procedures to follow in working with and analyzing ERTS data. Much of the early analysis effort concentrated on this particular data set. At present, CCTs from two data sets have been received for the Colorado test sites, and the CCT data for two more images has been ordered.

C. The major problems involving this investigation at present are (a) lack of good quality, cloud-free CCT data over the two test sites and (b) the lack of small-scale aerial photography over the central Colorado area and the San Juan Test Site area. The first problem will be remedied with acquisition of two CCT tapes ordered December 8th. The second problem area cannot be resolved until such data can be collected in the late spring 1973. The availability of supplemental data over this test site from other sources is being investigated. A more detailed discussion of the current situation concerning the aircraft data is contained in a letter to Dr. Nicholas Short, a copy of which is attached as Appendix A to this report.

(E73-10033) AN INTERDISCIPLINARY ANALYSIS
OF ERTS DATA FOR COLORADO MOUNTAIN
ENVIRONMENTS USING ADP TECHNIQUES
Semiannual Report, 1 Jul. - 31 Dec. 1972
(Purdue Univ.) 18 p HC \$3.00 CSCL 08F

N73-15366

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D. Accomplishments During Reporting Period, LARS Progress

1. Cover Type Mapping Project.

The first frame of ERTS MSS data was collected over the Red River Valley area of Texas and Oklahoma, more commonly known as the Lake Texoma frame. Data was collected on July 25th and a tape containing the area was made available to LARS on July 26th. After arrival at Purdue by courier on the same day, the data was reformatted and analysis was initiated on July 27th. Personnel on this project concentrated on a detailed analysis of the Ouachita Mountain portion of the frame. A preliminary classification, involving ten spectral classes, was completed on July 28. This was followed by a surface observation mission, then a more detailed analysis utilizing 20 spectral classes. The Ouachita Mountain portion of this frame contains a large amount of forest cover as well as many water resources, agricultural and rangeland features, and geologic features of interest. Both clustering and maximum likelihood algorithms were utilized in the classification procedure.

Five different groups of forest cover could be defined by the analysis sequence. These included forested areas having different topographic positions and forested areas which had a low infrared response due to stress conditions (caused by a combination of topographic position and soil moisture conditions). Several forested areas had been aerially sprayed with 2,4,5-T, a chemical commonly used to kill deciduous trees for purposes of rangeland improvement. These areas were distinctly defined in the ERTS data because of their low infrared reflectance and were accurately mapped with the ADP techniques. In another area, 2,4,5-T had been applied in 1971 but had not killed the trees, and this year when observed from the light aircraft, the area (though affected) could not be visually distinguished from the surrounding forest regions. However this area could be accurately delineated in the infrared channels of the ERTS data and was mapped in the classification analysis sequence. In another area the native forest cover had been cut and wind-rowed, allowing native grasses to dominate the scene. The straight lines and rectangular corner features in this area indicated human activity, and the spectral characteristics measured by the ERTS scanner allowed mapping of this rangeland area.

A distinct banding effect, related to the geologic structure of the Ouachita Mountains, was also very evident in the classification results. Surface observation and aerial photos of this area indicated that the spectral differences causing this banding

were due to a number of different features--in some cases, limestone out-croppings caused a very distinct spectral response, and in other cases the banding effects were caused by a combination of topographic and vegetative responses.

Differences in water quality of several reservoirs were cited by local resource personnel as the reason for the distinct spectral differences found in the ERTS data, even though these differences were not particularly obvious to the eye from a light aircraft. Another example of the potential use of ERTS imagery was indicated by the accurate location and mapping of a reservoir which was not shown on even the most recent map of the area.

Rivers and areas which included Interstate Highway-75, power lines, a recently cut hay field, rangeland, and agricultural and range areas where a great amount of soil is exposed were also delineated and mapped. We believe that these preliminary results indicate a great deal of potential for the use of ERTS data in detecting and mapping land use changes and many aspects of the agricultural and forest resource situation.

We believe that one of the more significant aspects of the analysis sequence with this data was the investigation of a technique to relate ERTS analysis and surface observation data collection. The following sequence appears to be an extremely effective and efficient technique for obtaining meaningful analysis results: First, using CCTs of the MSS data, a preliminary analysis of the data based solely on the spectral characteristics is conducted. This is followed by a surface observation mission to obtain visual information and oblique color photography of particular points of interest in the test site area. Finally, a refinement of the analysis sequence making use of the surface observation data obtained is carried out, with many spectral classes possibly being involved. By following such a procedure one is able to concentrate the collection of surface observation data on points of particular interest in the entire ERTS frame.

The second point of particular significance in this analysis was that a difference in spectral response which appears to be primarily caused by variations in aspect was clearly indicated. This would imply that topographic variations will cause a significant influence on the analysis of ERTS data collected in the Colorado Test Site region.

ERTS data from the San Juan Test Site (Scene ID 1029-17190) was largely cloud covered, however, since a CCT was received October 16 and no other data were available at that time the tape was reformatted. Analysis of a small, cloud-free section of

this data has further confirmed the influence of topography and aspect on the spectral characteristics of the various cover types involved. Further analysis concerning the seriousness of this influence and methods for accurately classifying cover types (in spite of such spectral variations due to topography) are continuing, using both the one existing frame of ERTS data in the Colorado Test Site area and the Ouachita Mountain test area data.

Since most of the upper mountain area is now covered with snow, it is anticipated that a majority of the cover type mapping analysis during the next several months will be concentrated on Frame no. 1047-17200 which is cloud-free and does cover the test site. It is anticipated that the CCT for this data will arrive very soon.

2. Geomorphology Project.

Initial analysis of Colorado data; collected over the San Juan site - August 21, 1972, Scene ID 1029-17190 began during the latter part of October. The data set being analyzed is approximately 60% cloud covered. The extent and nature of the cloud cover precludes selection of large training areas free of either cloud or cloud shadow. The extensive cloud cover on this frame has caused some difficulty in separating certain spectral classes of water from cloud shadow. Further investigation into this problem has indicated an approach which may be successful in separating these classes.

An area along the southwestern corner of this data is relatively free of cloud and shadow problems and exhibits good geologic structure when examining the ERTS black and white imagery. This area, from Durango southward, is currently being analyzed with the primary objective being identification of the geology of the area.

Preliminary results from this analysis indicate that coarse-textured alluvium, topographic shadows, and surficial material exposed to direct sunlight can be successfully discriminated. Additionally, it appears that hogback topographic features and associated rock units can also be accurately identified. These initial results indicate the applicability of ERTS data for compiling maps of alluvial gravels and general topographic form. However, it should be emphasized that caution must be taken in interpreting the classification results. When dealing with subsurface parent materials, it is assumed that these materials are manifested as distinguishable classes on the surface.

Vegetative cover type, soil type, and moisture content may adversely affect separability of the classes being considered. Furthermore, reliability of classification results cannot be fully assessed without the existence of high quality ground information. Presently, old geologic maps are the only source of ground information available for the area of study.

Another area of activity over the past few months has been in the topographic modeling portion of the study. Emphasis has been placed on digitizing topographic data for the San Juan site, especially for those areas that have been field checked by INSTAAR.

3. Hydrologic Feature Survey Project

The efforts in this area have thus far largely been concentrated on the analysis of the Lake Texoma data. This analysis involved the mapping of small streams and the determination that such mapping could be effectively carried out with the resolution of the ERTS data. A study of spectral characteristics of reservoirs in the area was also conducted. At least four distinct spectral differences of water in these reservoir areas have been defined and mapped. It is believed that in some cases the spectral differences are caused by variations in water quality while in other cases variations in water depth are the cause of the spectral response defined in the ERTS data.

A frame of data collected on November 1st over the San Juan Test Site (Scene ID 1101-17203) was received at LARS near the end of the reporting period and has been reformatted. There is a great deal of snow cover present in this frame as well as some cloud cover. Analysis of this data will concentrate on the following objectives:

1. Spectral discrimination and automatic mapping of clouds, snow cover, partial snow cover, mountain lakes, topographic shadow, and cloud shadow.
2. Determine the aerial extent of the various types of surface cover (or clouds).

It is believed that we will learn a great deal concerning the capability to spectrally differentiate cloud and snow cover as a result of this analysis. It is also anticipated that this frame will be useful in further tests of our capability to spatially overlay one data set on another. It is anticipated that some problems will be encountered in this area when the scene has changed so drastically (as in this case--from no snow cover to a large amount of snow cover).

E. INSTAAR Project Progress Report to Date

The majority of the work at INSTAAR has been centered on obtaining various types of data from different sources to use in developing base maps of the various cover types and their characteristics in the study areas. This work has progressed very well, and base maps of the cover types have been prepared for a large portion of both test sites. Base map data in the form of quad-centered and rectified photography of the southern region of the San Juan Test Site was procured from the U. S. Forest Service. This imagery is based upon high altitude photography flown by Mark Hurd and processed to correspond exactly with the 7.5' series USGS quadrangle maps. However, most of the San Juan Test Site is not covered by this photographic data.

U. S. Forest Service timber type maps (planimetric) and some dated black and white aerial photography have been obtained from the U. S. Forest Service for both the Indian Peaks and San Juan Test Site areas. Photography from NASA Missions 205, 211, and 213 has been received by INSTAAR. The flightlines have been logged and interpretation of this photography has been proceeding. This photography is proving extremely useful for developing the base map data and for extending the surface observation data for areas which were not reached during the abbreviated 1972 summer field season. ERTS-1 imagery is being catalogued as received, and preliminary analysis of this data is being pursued. Magnification of the ERTS imagery and color enhancement techniques are being utilized in this analysis. Mapping of the various cover types using both field and surface observation data has been based on USGS 7.5' quadrangle sets for both study areas. 15' quads are being used when 7.5' quads are not available.

The following discussion summarizes the work completed to date by each of the subproject analysis groups.

The ecological inventory: This effort has been divided into two sections. The macro-vegetation study was initially involved in the preparation of base information from existing sources as a prelude to the necessary field work. Acquisition of existing maps provided a major information source. The maps obtained included USGS topographic maps, national forest planimetric maps for San Juan, Rio Grande, and Uncompahgre National Forests, and also timber type maps for these same national forests. All map sources were catalogued and cross-indexed for the overlapping coverage. This has proved to be a useful reference system as specific map coverage was requested. In addition, all available Hurd aerial photographic map documents

for the San Juan Mountain Test Site have been included in this reference system. Aerial photography of specified sites were ordered from the U. S. Forest Service.

Based on familiarity of the San Juan Test Site, selection was made from major forested cover type categories. Several training or test sample areas from each cover type were then designated. Two criterion were used in this procedure: (1) homogeneity of the forest stands and (2) a minimum size of 40 acres. Examples of each cover type were well scattered throughout the San Juan Test Site. A total of 47 training or test sample areas have been thus defined.

Each of these 47 designated areas was located and cover types were confirmed and boundary alterations noted in the field. It was found that since the existing aerial photography was ten to twelve years old there were a number of boundary alterations involved. Ground truth photography was obtained for each of the sample areas. In addition, extensive field reconnaissance of selected areas was carried out. These areas included the Wolf Creek Pass, watershed of the east fork of the San Juan River, Williams Creek, and the Piedra River drainage northwest of Pagosa Springs, and the Yankee Boy Basin, Mount Sneffels, and Dallas Divide areas west of Ouray.

Upon completion of the summer field work, the field notes were converted into a more usable format. The transfer of all 47 sample areas under the base maps (either USGS or USFS planimetric) was completed. Particular attention was directed toward boundary delineations to account for sight changes. A permanent reference file is being established for the ground photography of these 47 designated sample areas.

A system of symbol designation for vegetation mapping has been developed for the forested areas. The system was derived so as to be applicable to all mountainous regions in Colorado. Preliminary interpretations of the RC-8 color infrared photography that has been obtained shows clear distinction among vegetative cover types. ERTS imagery received thus far or borrowed from the Colorado School of Mines has been processed with color enhancement techniques. This analysis indicates definite detectable differences among various cover types.

Currently, efforts are being directed toward preparation of the training/test site information for LARS. This includes all maps, ground photographs (B/W) and other information needed by LARS for their phase of the analysis efforts.

1. Macro-Vegetation Study.

The initial work load was to prepare base information from existing sources preliminary to necessary field work. The first major information source came from the acquisition of existing maps. These included USGS topographic maps, National Forest planimetric maps for San Juan, Rio Grande and Uncompahgre National Forests, and timber type maps for these National Forests. All map sources were catalogued and cross-indexed for the overlapping coverage. This has proved to be a useful reference system as specific map coverage was requested. In addition all available Hurd Aerial Photographic Map Documents for the San Juan Mountains Test Site have been included in this reference system. Aerial photography of specified sites were ordered from the U. S. Forest Service.

Based upon familiarity of the San Juan Test Site selection was made for major forested cover type categories. Several training samples of each cover type were preselected from USFS aerial photos. Two criterion were used in this selection; homogeneity of the stands and a minimum size of 40 acres. Examples of each cover type were well scattered throughout the San Juan Test Site. This resulted in a total of 47 training samples.

Each of the 47 training samples was located, cover type confirmed and boundary alterations noted to up-date the area since most aerial photos were taken 8-12 years ago. Ground truth photography was completed for each training sample (35mm color slides and B/W prints). In addition extensive field reconnaissance of selected areas was done for Wolf Creek Pass; watershed of the East Fork of the San Juan River; Williams Creek, and Piedra River Drainage northwest of Pagosa Springs; and the Yankee Boy Basin, Mt. Sneffels and Dallas Divide areas west of Ouray.

Upon completion of this season's field work the field notes were converted into a usable format. The transfer of all 47 training samples onto the base maps (either USGS or USFS planimetric) was completed. Particular attention was directed toward boundary delineations to account for site changes in the aerial photography. The film processing has been completed and a permanent reference file of ground photography of the training samples is being established.

A symbol system of vegetation mapping has been developed for the forested area. This system was derived to be applicable to all mountainous regions in Colorado.

Preliminary scans of RC-8 color IR of the western one-third of the San Juan Test Site show clear vegetational distinctions. What ERTS-1 imagery was received by INSTARR and borrowed from the Colorado School of Mines has been examined. Color enhancement of these available ERTS-1 imagery definitely illustrates detectable differences among cover types.

Currently, efforts are being directed toward preparation of training site information for LARS. This includes all maps, ground photographs (B/W) and other information requested by LARS.

2. Micro-Vegetation Study.

The summer field season was devoted entirely to detailed mapping of micro-vegetation cover types in the two intensive study sites in the San Juans. At the termination of the field season, attention was turned to preparation of ground truth maps. Blue line maps and color coded classification maps have been completed.

A dendrogram series is being set up in an effort to simplify selection of the appropriate level of sophistication for computer mapping based upon satellite imagery. Recently work has begun on increasing mapped tundra communities based upon Mission 213 underflight imagery. As this data just arrived, and NASA was unable to provide the necessary San Juan underflight data, this phase of the project has been somewhat hindered.

Preliminary "first look" exercises involving 1:1,000,000 ERTS imagery (under magnification) indicates more than simple tundra-timber discrimination should be attained.

3. Hydrology Project.

Work to date has largely focused upon creation of a lake inventory for the Colorado Front Range study area. The following data is recorded for each identified lake (much from 1:24,000 USGS quads):

- Lake name
- Location to the nearest half minute
- Length of the long axis to the nearest 50 ft.
- Length of B axis to the nearest 50 ft.
- (B axis = longest length perpendicular to the long axis)
- Orientation of long axis using a North Grid
- Height of contour immediately below the lake

The following quadrangles have been completed: Trail Ridge, McHenry Peak, Isolation Peak, Monarch Lake, and East Portal. After completion of all quads within the Front Range Study area, lake areas and depth will be recorded.

4. Geomorphology Project.

The geomorphology efforts have been centered on the San Juan Mountain Test Site and are closely related to work being conducted in this area under existing programs. Their photo mapping of selected areas within the range has been carried out on base maps of 1:24,000 scale. During the summer these maps include: scree slopes, areas of bedrock, till mantled bedrock, avalanche chutes and slide areas, slumps and mudflows, moraines, rock glaciers, protalus ramparts, alluvial fans, valley fill, and cirques. The mapping of this information has now been completed for eleven 7.5' USGS quadrangles. These quads are: Telluride, Gray Head, Redcloud Peak, Ironton, Silverton, Snowdon Peak, Howardsville, Storm King Peak, Rio Grande Pyramid, Weminuche Pass, and Little Squaw Creek.

Study sites of known areas have been selected for detailed analysis and interpretation of ERTS imagery. These study sites are scattered over the various quadrangle areas in order to reduce the possibility that they would all be covered by clouds during any single pass of either aircraft or the satellite.

5. Interpretation Techniques Study.

A computer program which will utilize digitized topographic data has been completed. This program will predict areas of shadow within each of the study areas. The shadow patterns will be generated to correspond to the seasonal as well as the daily time of each satellite overpass.

6. Data Collection Platform.

Preparation of the instrumentation for the DCP and necessary interface with its hardware has been completed. The DCP has been installed and is functioning normally on Niwot Ridge in the Colorado Front Range.

A liaison has been established to Julian Pike with the National Center for Atmospheric Research for use of their radiation measurement system and interpretation with the current instrument array.

F. Planned Projects During the Next Period.

During the next bi-monthly reporting period, work will be continued in the following areas:

1. Continued analysis for automatic cover type mapping of the cloud-free segments of data from Scene ID 1047-17200.
2. Investigation into the ability to spectrally differentiate between clouds and snow cover.
3. Automatic determination of the ^{area} aerial extent of snow cover.
4. Delineation and identification of forest cover types for the September 8, 1972 pass over the San Juan Test Site, Scene ID 1043-17200.
5. Determination of topographic effects on spectral response from the above data set.
6. Continued work in digitizing and analyzing topographic data from Howardsville and the Silverton quadrangles.
7. Geomorphic analysis will continue on data collected over the Durango area of the San Juan site. Data available over this area, collected November 19, 1972 (Scene ID 1119-17195) will be analyzed.

G. Significant Results.

Included above.

H. Publications.

Landgrebe, D. A., R. M. Hoffer, F. E. Goodrick, and Staff. 1972. "An Early Analysis of ERTS-1 Data". Invited paper presented at the NASA Symposium on Preliminary Results of ERTS Data Analysis, Goddard Space Flight Center, September 29, 1972. LARS Information Note 092972, 21 pp.

Hoffer, R. M. 1972. "Agricultural and Forest Resource Surveys from Space". Invited paper presented at the Forum Session of the 23rd International Astronautical Congress, Vienna, Austria, October 8-15, 1972. LARS Print 100972, 12 pp.

A copy of the first report was submitted with a previous bi-monthly report. The second report is in preparation.

- I. No additional comments or suggestions.
- J. A change in the standing order is being contemplated.
The appropriate information will follow.
- K. No new ERTS Image Description Forms are submitted.
- L. Appropriate ERTS Data Request Forms for the last bi-monthly period are attached.

-13-

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January 3, 1973

317/749-2052

Dr. Nicholas M. Short
NASA
Code 652
Goddard Space Flight Center
Greenbelt, Maryland 20771

RE: Aircraft Underflight Support for ERTS Contract

Dear Dr. Short:

In response to your request for information concerning the aircraft underflight program for our ERTS-1 contract, I believe the following comments should be made:

1. Aircraft underflight data is absolutely necessary to the satisfactory completion of our ERTS-1 project. Small scale, good quality aerial photography is required for selection of homogeneous areas of the various cover types involved in the analysis, in order to (1) select adequate training and test sample areas to use in obtaining classification results and particularly for evaluating these results. It is possible to use a clustering approach to classify ERTS data without any aerial photography or even maps, but one does not know how to interpret the spectral categories thus designated, and no indication of the accuracy of the classification can be obtained without aerial photography of the area classified. (2) In order to develop a capability to predict future capabilities of ADP based on the spectral characteristics of the various materials, study of these spectral characteristics is required using the test sites selected on the basis of the aerial photography. We feel very strongly that good quality small-scale aerial photography is essential to the satisfactory fulfillment of our ERTS contract if we are to properly evaluate the effectiveness and the potential of ADP. It could also be pointed out that the aerial photography requested from NASA is an integral and essential part in the preparation phase of our Skylab project which will be conducted in approximately the same geographic area.

2. Data Requested. RB-57 photography has been requested for three areas. These include (a) the Colorado area, (b) Indian Peaks Test Site, and (c) San Juan Mountain Test Site. The Colorado area was to be flown on either Mission 205 (May 30-June 16, 1972) or Mission 208 (July 5-21, 1972). The Indian Peaks

Dr. Nicholas M. Short
January 3, 1973
Page Two

and San Juan Mountain Test Sites were to have been flown during the following time periods: Sept. 5-15, 1972, March 10-20, 1973, April 10-20, 1973, and June 15-30, 1973. The early spring flight missions are of particular importance in evaluating snow cover changes during the spring run-off period and for positive differentiation between snow cover and clouds (which at present appears to be somewhat difficult on much of the ERTS imagery). However they do not have as high a priority as does the summer-time base line data for use in evaluation of classification results of all cover types.

3. Results to date include the following: Data in Colorado was flown during Mission 205 in early June. This photography was received late in September. Image quality was good, but it did not cover any of our test site areas.

No data was collected over the Colorado test site during Mission 208.

Mission 211 was flown in mid-September and data were received a month later. We consider this turn-around time to be extremely good and are most appreciative for NASA's efforts. Data quality was generally good with the exception that the main roll containing data over the Indian Peaks Test Site exhibited alternating pitch from frame to frame due to the camera not having been locked in position. This makes the interpretation of the data more difficult. During Mission 211, all the Indian Peaks Test Site was covered and other areas to the northeast and south of the test site were also covered. However these other areas are not of interest to us and were not requested by us. Because of the joint cooperative nature of the project, both University of Colorado and Purdue were to receive copies of the imagery obtained. However personnel at INSTAAR have not yet received the two rolls of color infrared film collected by the Zeiss camera during Mission 211. This data is required, in view of the poor photogrammetric quality of the RC-8 imagery, for mapping cover type distribution over the Indian Peaks sites.

In summary, none of the baseline data from the Colorado area has been obtained nor has any data been obtained over the San Juan Mountain Test Site. However useable data has been obtained over the Indian Peaks Test Site.

4. For the data collected, the quality appears to be very good. This data is proving extremely useful in mapping out basic cover types and selecting training and test areas for use in the automatic data processing analysis sequence. However, many phases

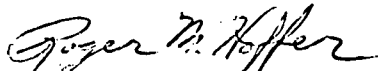
Dr. Nicholas M. Short
January 3, 1973
Page Three

of the analysis are being hampered because of a lack of ERTS CCT data that is cloud-free over the Indian Peaks Test Site, where we do have aerial photography, and a lack of aerial photography over the San Juan Mountain Test Site where we do have good quality ERTS data. However we have learned from another PI that NC-130 data has been obtained over the San Juan Test Site area and that there is a possibility that U-2 imagery exists over these test sites. We are therefore trying to obtain further information concerning these data sources. We have also been working closely with the U. S. Forest Service and using existing cover type maps and aerial photos as a secondary source of support for the investigation. These data sources are far from adequate however.

5. By emphasizing analysis with a clustering approach, research over both test sites will move forward in a positive manner during the next several months. However, as an absolute minimum, the acquisition of good quality small scale aerial photography over the San Juan Test Site during the spring and summer of 1973 will be absolutely essential to a satisfactory evaluation of the classification results obtained.

I trust this material will bring you up to date on the status of our aircraft data and its relation to our investigations. If you have any questions concerning this report, please call myself or Dick Mroczynski.

Sincerely yours,



Roger M. Hoffer
Principal Investigator
UN 103

RMH:sdh

CC: ✓ R. P. Mroczynski
D. A. Landgrebe
M. F. Baumgardner
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